First Year Progress Report for Multi-Objective Optimal Scheduling for Space Science Applications

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Summary of First Year Progress

During the first 10 months of the grant period we made substantial progress towards building and demonstrating a multi-objective multi-participant schedule optimization system for space science missions. At the start of the project we decided to empirically evaluate the benefits of the multi-objective approach for the JWST mission in the first year of the grant and to use the results of the evaluation to inform the end design of the model based system we are building. This resulted in rearranging items in the original project schedule where empirical evaluation of the system on JWST did not occur until the end of the first year. We first outline our accomplishments for the year. Next, we summarize the external impacts that the grant has had on the greater NASA and planning and scheduling communities. Next, we present an updated project schedule showing how the grant objectives will be achieved by the end of the grant period. The last section summarizes public out reach activities associated with the grant.

Multi-Objective system architecture (1st quarter) - The first task we did was to design and code a system architecture for multi-objective scheduling that integrate existing software components. The architecture integrates the JAVA based GDE3 evolutionary algorithm driver with the LISP based SPIKE scheduling engine. The GDE3 algorithm provides support for multi-objective evolutionary algorithms while SPIKE provides support for modeling and scheduling space telescope domains. Both systems utilize object oriented designs that allow new application domains to be created by defining methods that implement the semantics of the domain.

JWST scheduling test-bed (1st – 2nd quarter) - The multi-objective system architecture was instantiated to implement a JWST scheduling test-bed that allows multi-objective algorithms to be exercised scheduling JWST observations. The system utilizes constraints and resource data from JWST mission simulators. The test-bed incorporates three objectives to minimize wasted space, missed observations, and momentum build-up. In addition, the test-bed allows multiple options for integrating JWST scheduling decisions into the multi-objective framework.

Initial JWST Experiments (2nd – 3rd quarter) - A set of experiments were performed utilizing the test-bed using the JWST Science Observation Design Reference Mission as input. The experiments verified the utility of multi-objective scheduling in the JWST domain and explored alternative techniques for exploring the search space.

Model based Scheduler Design (3rd – 4th quarter) - We have started investigating how to abstract the core features of the class of problems we are considering into re-useable model elements, and how/where to include problem-specific customizations that are required to adapt the model to different scheduling problems. This effort will continue through the end of Year 1 and on into Year 2.

Multi-User support (3rd – 4th quarter) - Our basic approach of multi-objective optimization provides a natural mechanism for multiple users to specify their goals and objectives in a quantifiable way. We have begun the investigation of how to present the results of multi-objective optimization to all or a subset of users, to provide live updates, and to provide controls for exploring the Pareto tradeoff surface in a collaborative environment. We have investigated some commercial software approaches as well as open source technologies, and have done some initial prototyping with the JavaFX dynamic scripting language.

Summary of External Impacts

- A paper publishing the results of our initial experiments titled "Multi-Objective Evolutionary Algorithms for Scheduling the James Webb Space Telescope" was accepted for publication at the 2008 International Conference on Planning and Scheduling (ICAPS).
- Mark Giuliano is on the organizing committee and Mark Johnston, the Co-I for this grant, is on the extended program committee for the Over Subscribed Planning and Scheduling workshop to be held at the 2008 ICAPS conference.
- The PIs will give an invited talk at the 2008 Astronomical Data Analysis Software and Systems conference titled Multi-Objective Optimal Scheduling for Space Science Applications.

Updated Project Schedule

An updated project schedule is included below. For ease of comparison the original project schedule as submitted in the grant proposal is included in Appendix A. The primary difference between the updated project schedule is that the design and implementation of a model based scheduling application was delayed until the second half of the first year, and experimentation and analysis was moved forward to the second quarter. The motivation for this change was to allow initial experimental results to drive the design of the model based system.

Year 1	**1st qtr**	**2nd qtr**	**3rd qtr**	**4th qtr**
	Designed and built a multi-objective system architecture. Implemented JWST scheduling test-bed based Empirically evaluated JWST test-bed verifying approach Evaluated design options for model based approach Prototyped components for multi-user support			
			Design and code model based representation	
Year 2	**1st qtr**	**2nd qtr**	**3rd qtr**	**4th qtr**
	JWST testbed multi-participant experimentation and analysis based on model based representation			
			Architecture changes based on JWST experimentation	
				Design of 2nd mission testbed
Year 3	**1st qtr**	**2nd qtr**	**3rd qtr**	**4th qtr**
	Implementation of 2nd mission testbed			
		2nd mission testbed experiment and analysis		
		JWST testbed extensions and experiments.		
				Documentation Grant Closeout

Public Outreach Efforts

During the year the PI submitted and received funding for an Education and Public Outreach (E/PO) proposal in response to the AISR portion of the NASA Research Announcement for Research Opportunities in Space and Earth Sciences (NNH06ZDA001N). The proposal will redesign the existing Women's Science Forum program based on the planning and scheduling research funded by the AISR grant. The program will be offered to up to 100 high school and middle schools from the Baltimore area and aims to bring women into Science Technology and Math (STEM) careers. The program is planned for the spring of 2009.

Appendix A. Submitted Project Schedule

Year 1	**1st qtr**	**2nd qtr**	**3rd qtr**	**4th qtr**
	Define model-based representation Develop system architecture for reusable design framework			
		Design and implementation of JWST testbed		
			Implementation of design framework	
				Proof of concept experimentation on JWST
Year 2	**1st qtr**	**2nd qtr**	**3rd qtr**	**4th qtr**
	Architecture changes based on proof of concept experimentation			
		JWST testbed experimentation and analysis		
				Design of 2nd mission testbed
Year 3	**1st qtr**	**2nd qtr**	**3rd qtr**	**4th qtr**
	Implementation of 2nd mission testbed			
		2nd mission testbed experiment and analysis		
		JWST testbed extensions and experiments.		
				Documentation Grant Closeout